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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification [6] :
B60C 23/00, 23/02, G08B 1/08, 21/00, G01N 9/24

A1

(11) International Publication Number: WO 99/52722

(43) International Publication Date: 21 October 1999 (21.10.99)

(21) International Application Number: PCT/US99/08020

(22) International Filing Date: 13 April 1999 (13.04.99)

(30) Priority Data:
60/081,518 13 April 1998 (13.04.98) US

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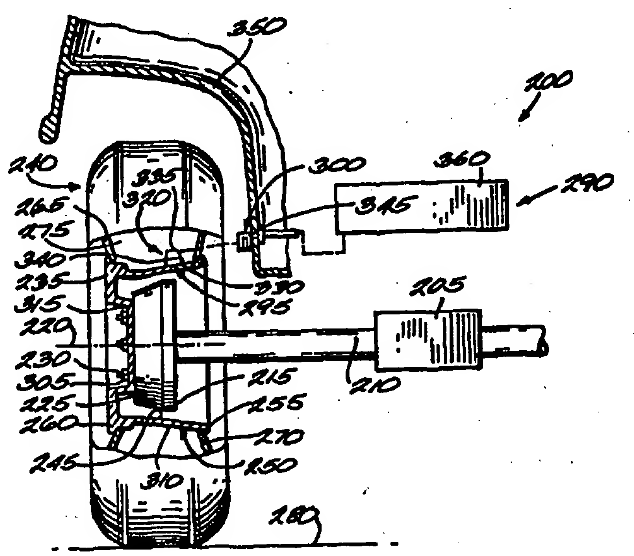
(81) Designated States: US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: METHOD AND APPARATUS FOR SENSING TIRE PRESSURE IN A VEHICLE WHEEL



(57) Abstract

The invention provides a wireless tire pressure sensing method and apparatus (290). The method and apparatus (290) include a transducer (295), a power source, a transmitter, and a receiver (300). The transducer (295) measures a pneumatic pressure and/or temperature and/or wheel speed that is converted into a wireless data signal by the transmitter (295). The receiver (300) receives the signal from the transmitter and thereafter transfers the signal to a controller (360). The method and apparatus may use one or more antennas to transmit and/or receive data between the transmitter (295) and the receiver (300).

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METHOD AND APPARATUS FOR SENSING TIRE PRESSURE IN A VEHICLE WHEEL

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/081,518, filed April 13, 1998.

BACKGROUND OF THE INVENTION

The invention relates to a method and an apparatus for measuring pneumatic pressure, and more particularly, to a method and an apparatus for measuring and transmitting tire pressure.

There are a variety of systems that monitor tire pressure. Some systems do not provide electrical power to sensors and some do not monitor pressure when a tire is rotating.

One type of system monitors tire pressure using radio frequency links. These systems may require strong radio frequency transmissions to transfer data between a sensor and a receiver. However, strong radio frequency transmissions can drain a power source quickly. When weaker signals are used, system life may be extended at the cost of compromised data integrity.

Other remote monitoring tire pressure systems may require transceivers to be in close proximity with one another and may require structural modifications to the vehicle wheel hub when retrofitted to a vehicle. As illustrated in the prior art device 100 of FIG. 1, a first transceiver 105 is mounted in close proximity to a second transceiver 110. Because the first transceiver 105 is connected to a wheel hub 115 through an aperture (not shown), the prior art device can require that the wheel hub 115 be drilled, which can complicate after-market installations.

SUMMARY OF THE INVENTION

Accordingly, the invention provides a wireless tire pressure sensing method and apparatus. The method and apparatus comprise a transducer, a

power source, a transmitter, and a receiver. The transducer measures a pneumatic pressure and/or temperature that is converted into a wireless data signal by the transmitter. The receiver receives the signal from the transmitter and thereafter transfers the signal to a controller. The method and apparatus may use one or more antennas to transmit and/or receive data between the transmitter and the receiver. The transducer, the power source, and the transmitter can be positioned within any number of tires of a vehicle. It is envisioned that the transducer, the power source, and the transmitter may be formed unitary with an antenna.

In another aspect of the invention, the tire pressure sensing method and apparatus use an antenna to detect wheel speed. Using either an existing or a separate antenna positioned outside of the tire, the rotational speed of the wheel is received by the receiver. The signal passes to the controller through a wire or a wireless bus.

The disclosed method and apparatus can continuously monitor pneumatic tire pressure, temperature, and wheel speed regardless of tire rotation. The method and apparatus provide a technology that is easily retrofitted to vehicles without any mechanical modifications and further provide a technology that can detect wheel speed with few parts. These features, as well as other advantages of the invention will become apparent upon consideration of the following detailed description and accompanying drawings of the present embodiments of the invention described below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front perspective view of a prior art device;

FIG. 2 is a front perspective view of a device for sensing tire pressure; and

FIG. 3 is a cross sectional perspective view of a transducer/transmitter of FIG. 2.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

FIG. 2 shows a section of a vehicle 200. The vehicle 200 has a frame 205 (partially shown in FIG. 2) and a frame member 210 supporting a wheel end housing 215. The wheel end housing 215 is mounted for rotation relative to the frame member 210 about an axis 220. The wheel end housing 215 includes a wheel mounting surface 225 and a plurality of rods 230 extending axially from the end housing 215. The rods 230 are threaded to receive lug nuts 305 that secure a wheel rim 235 to the wheel mounting surface 225. A tire 240 fits around the rim 235 and is filled with compressed air. While only one tire 240 is shown, any number of tires are envisioned in this embodiment. Persons of ordinary skill in the art will appreciate that the tires may be made of many materials such as synthetic rubber reinforced with nylon, fiberglass, or steel, for example, that can have many mounting configurations.

The rim 235 has a cylindrical portion 250 having an inner and an outer surface 245 and 310 terminating at end portions 255 and 260. A valve orifice (not shown) for receiving a valve stem (not shown) of the tire 240 is formed in one of two sidewall portions 265 and 270. The rim 235 further includes an end wall 315 near the end portion 260. The end wall 315 has a plurality of apertures (not shown) passing therethrough to receive the rods 230 that are secured to the wheel rim 235 by the lug nuts 305.

As further shown in FIG. 2, the tire 240 is mounted on the rim 235 and encloses a channel 275 defined by the sidewall portions 265 and 270 and the cylindrical portion 250. As shown, the tire 240 supports the vehicle on a surface 280.

As shown in Fig. 2, the vehicle 200 also includes a wireless tire pressure sensor apparatus 290. The apparatus 290 includes a transducer/transmitter 295 attached to the cylindrical portion 250 of the rim 235 and a receiver 300 or a transceiver positioned away from the

transducer/transmitter 295. While the transducer/transmitter 295 is shown as a unitary structure, the device may be comprised of separate components including a separate transducer and a separate transmitter, for example.

As best shown in FIG. 3, the transducer/transmitter 295 is enclosed within a first housing 320. The first housing 320 is formed of a molded plastic material or rubber in a shape that comprises a circular portion 330 and a trapezoidal portion 335. The trapezoidal portion 335 projects from the circular portion 330 having a mounting surface (not shown) which is secured to the outer surface 310 of the rim 235 (shown in FIG. 2). In a preferred embodiment, the mounting surface is secured to the rim using an adhesive (not shown). Although the first housing 320 may be joined to or formed unitary with the valve stem, preferably, the first housing 320 is positioned away from the valve stem.

The first housing 320 also encloses a power source (not shown) that is coupled to the transducer/transmitter 295. While any portable power source is appropriate provided size and power requirements are satisfied, the power source preferably comprises a low drain battery cell such as a lead or a lithium ion cell, for example. The battery may be a permanent or a replaceable cell that can provide uninterrupted power to the transducer/transmitter 295, preferably, for the useful life of the tire 240. Because each transducer/transmitter 295 is preferably powered by a battery rather than a portion of an electromagnetic field, the wireless tire pressure sensor apparatus 290 can transmit data over greater distances with less attenuation and loss than some conventional electromagnetic powered systems. Moreover, the wireless tire pressure sensor apparatus 290 does not unnecessarily consume power in converting a portion of an electromagnetic field into useable power. Furthermore, the wireless tire pressure sensor apparatus 290 may employ a sleep mode to conserve power when, for example, the vehicle 200 is not in use.

The electronics of the transducer/transmitter 295, the receiver 300 or transceiver are preferably integrated circuits. As shown in FIG. 3, the integrated circuit of the transducer/transmitter 295 includes a circuit 370 mounted within a recess 375 of the first housing 320 away from a pair of ferrite pole segments 420. A cover 380 is secured to an interior surface 385 of the first housing 320 to partially enclose the circuit 370. The cover 380 comprises a lower portion 385 unitary with two lateral portions 390 and 400 that partially surround and support the circuit 370. The lateral portions 390 and 400 incorporate a flange 405 having an exposed surface 410 that abuts circuit 370 while the lower portion 385 has an air channel 425 that allows compressed air to flow to the circuit. Preferably, the air channel includes an active or, as shown, a passive filter 430 that prevents dirt, moisture, and/or other contaminants from reaching and impairing the transducer/transmitter 295.

The transducer/transmitter 295 further includes a pressure sensor and a temperature sensor. The pressure sensor is preferably a silicon surface micro-machined integrated circuit pressure sensor as shown and described in U.S. Pat. No. 5,507,171, entitled "Electronic Circuit for a Transducer", which is incorporated herein by reference. The temperature sensor is preferably an integrated circuit temperature sensor as shown and described in U.S. Pat. No. 5,795,069 entitled "Temperature sensor and Method", which is incorporated herein by reference. Additional details concerning the electronics of the transducer/transmitter 295 or the receiver 300 are disclosed in U.S. Patent No. 5,824,891 entitled "Method and Apparatus for Efficiently Phase Modulating a Subcarrier Signal for an Inductively coupled Transponder", which is incorporated herein by reference. The present specification integrates the methods, apparatuses, and disclosures described in each of the above-cited U.S. patents.

The transducer/transmitter 295 may further use a coil 340 unitary with the first housing 320 or as shown in FIG. 2, disposed within a recess 365 of the first housing 320. Preferably, the coil 340 is connected to the circuit 370 through a pair of conductors 415 enclosed by the first housing 320. The receiver 300, positioned away from the transducer/transmitter 295, likewise may have a coil 345 disposed within a recess or, as shown in FIG. 2, unitary with a second housing 355 that is positioned outside of the tire 240 and connected to a portion of the vehicle 200, such as a wheel well member 350, for example. Preferably, the receiver coil 345 is within three tenths of a meter of the transducer/transmitter coil 340. Those skilled in the art will recognize that either coil 340 or 345 can be separated from either the transducer/transmitter 295 or the receiver 300, respectfully, and function as a stand-alone antenna. It is envisioned that a wheel speed sensor (not shown) of a known type may be incorporated into the wireless tire pressure sensor apparatus 290. A third coil (not shown) positioned outside of the tire 240 and connected to a portion of the vehicle 200 may be tuned to receive wheel speed signals which are conditioned by the receiver 300 and passed to a controller 360. The receiver 300 or the controller 360 may distinguish the signals by frequency, for example. In some systems, the maximum frequency of a speed sensor is approximately one-kilohertz, whereas in one exemplary embodiment of the invention, pneumatic pressure and temperature data is transmitted at a wireless frequency above approximately fifty-kilohertz. Of course, other frequencies or modulation designs may also distinguish pressure and temperature data from rotational speed data just as a second receiver can also be used to receive rotational speed data.

While the transducer/transmitter 295, the receiver 300, and the wheel speed sensor as shown are analog devices, in other embodiments one or more of the devices may be a digital device.

The controller 360 may encompass any known electronic controller such as an electronic control module or an antilock brake controller, for example. Such controllers are well known to those skilled in the art and thus are not described here in greater detail.

In operation, the temperature sensor and the pressure sensor generate electrical signals as the sensors are subject to air temperature and air pressure, respectively within the tire 240. The transducer/transmitter 295, in turn, translates these electrical signals into one or more wireless signals that are transmitted to the receiver 300. When the wireless signals are received, they are decoded and relayed to the controller 360.

Because one transducer/transmitter 295 and one receiver 300 are used with each tire 240 of a vehicle, the wireless tire pressure sensor apparatus 290 can reduce transmission distances between the transducer/transmitter 295 and the receiver 300 by a factor of approximately three and reduce crosstalk in comparison to some single antenna systems. Moreover, each tire 240 is easily identified as each transducer/transmitter 295 is dedicated to a given tire 240. In other embodiments, the receivers 300, or the controller 360 of the vehicle 200 can encode data with tire identification data unique to each tire 240.

In view of the foregoing description and illustrations, it should be apparent that the transducer/transmitter 295 can monitor the mechanical condition of a rotating or stationary tire 240. The transducer/transmitter 295 is a sealed device shielded from moisture and other contaminants. Moreover, it can be attached to the rim 235 through an adhesive without counterbalancing. It is envisioned that the transducer/transmitter 295 can be integrated to or formed unitary with any part of a tire, such as a tire wall for example, which would simplify tire and transducer installations.

Many other extensions and alternatives of the invention are possible. For example, the wireless tire pressure sensor apparatus 290 discussed above can be linked through a wire or a wireless bus to other vehicle systems such as

a driver information system that alerts the driver to unusual vehicle conditions and/or chassis, engine, and/or brake control systems that compensate for any unusual bias such as an unusual yaw rate, for example. In some alternative embodiments a portion of the tire 240, such as for example, a portion of a tire cord may serve as an antenna. In another alternative, the passive sensor coil of the wheel speed sensor may serve as the receiver 300 antenna. In this case, the passive sensor coil would receive wireless signals having pneumatic pressure, pneumatic temperature, and rotational speed data. In yet another alternative, one transducer/transmitter 295 may be enclosed within each tire 240 of a vehicle and communicate with a single receiver 300. Of course, a tunable antenna or multiply tuned antennas could distinguish the wireless signals transmitted from each transducer/transmitter 295 and couple each signal to the receiver 300.

The foregoing detailed description describes only a few of the many forms that the present invention can take, and should therefore be taken as illustrative rather than limiting. It is only the following claims, including all equivalents that are intended to define the scope of the invention. Accordingly, other features and advantages of the invention are set forth in the following claims.

WHAT IS CLAIMED IS:

1. A system for remotely measuring a physical characteristic of a vehicle wheel, the system comprising:

a plurality of transducers, each transducer including a power source, a sensor connected to the power source, and a transducer connected to the power source; and

a receiver including a plurality of antennas, each antenna associated in a one-to-one relationship with the plurality of transducers, respectively, so that the plurality of antennas receive wireless data from the respective plurality of transducers.

2. A system as set forth in claim 1 wherein each transducer is positioned within a tire away from a valve stem of the tire.

3. A system as set forth in claim 1 wherein the transducer measures at least one of a pneumatic pressure and a pneumatic temperature.

4. A system as set forth in claim 1 wherein the wireless data includes data representing at least one of a pneumatic pressure and a pneumatic temperature.

5. A system as set forth in claim 4 wherein the antennas receive a rotational speed of a tire.

6. A vehicle comprising:

a frame member;

a plurality of wheels connected to the frame member for rotation relative to an axis, the wheels each having a respective wheel rim and a respective tire mounted on the rim; and

a system for remotely measuring a physical characteristic of a vehicle wheel, the system comprising:

a plurality of transducers, each transducer including a power source, a sensor connected to the power source, and a transducer connected to the power source; and

a receiver including a plurality of antennas, each antenna associated in a one-to-one relationship with the plurality of transducers, respectively, so that the plurality of antennas receive wireless data from the respective plurality of transducers.

7. A vehicle as set forth in claim 6 further comprising a second receiver positioned away from the transducer and the power source and in communication with the transmitter through a wireless link to receive data corresponding to a rotational speed of a tire.

8. A vehicle as set forth in claim 6 wherein each transducer is positioned within a tire away from a valve stem of the tire.

9. A vehicle as set forth in claim 6 wherein the sensor measures at least one of a pneumatic pressure and a pneumatic temperature.

10. A vehicle as set forth in claim 6 wherein the wireless data includes data representing at least one of a pneumatic pressure and a pneumatic temperature.

11. A vehicle comprising:

a pneumatic tire;

a transducer;

a transmitter interconnected to the transducer and a power source within the tire;

a receiver positioned away from the transducer and the power source outside the tire and in communication with the transmitter through at least one wireless link.

12. A vehicle as set forth in claim 11 further comprising a first antenna tuned to receive and transmit signals and coupled to the transmitter at a distance from the receiver and a second antenna coupled to the receiver and tuned to receive a data signal representative of at least one of a pneumatic pressure, a pneumatic temperature, and a rotational speed of a tire.

13. A vehicle as set forth in claim 11 wherein the transducer, the transmitter, and the power source are positioned away from a valve stem of the tire.

14. A vehicle as set forth in claim 11 wherein the transducer, the transmitter, and the power source are a unitary structure.

15. A vehicle as set forth in claim 11 wherein the transducer, the transmitter, and the power source are formed unitary with an antenna.

16. A vehicle as set forth in claim 11 wherein the wireless communication is representative of at least one of a pneumatic pressure, a pneumatic temperature, and a rotational speed of a tire.

17. A vehicle as set forth in claim 11 wherein the power source is a battery.

18. A method for monitoring a physical characteristic of a tire, comprising:

providing a transducer, a transmitter, a portable power source, and a receiver;

attaching a receiver to a vehicle frame member;

interconnecting the transducer to the transmitter and the portable power source within a pneumatic tire;

sensing a mechanical condition in the tire through the transducer;

transmitting a data signal corresponding to the sensed mechanical condition of the tire to the receiver.

19. A method as set forth in claim 18 wherein said portable power source is a battery.

20. A method as set forth in claim 18 wherein the transducer, the transmitter, and the portable power source are enclosed within a housing attached to a wheel rim.

21. A method as set forth in claim 18 wherein the vehicle fame member in part defines a wheel well.

22. A method as set forth in claim 18 further comprising providing an antenna to detect tire speed.

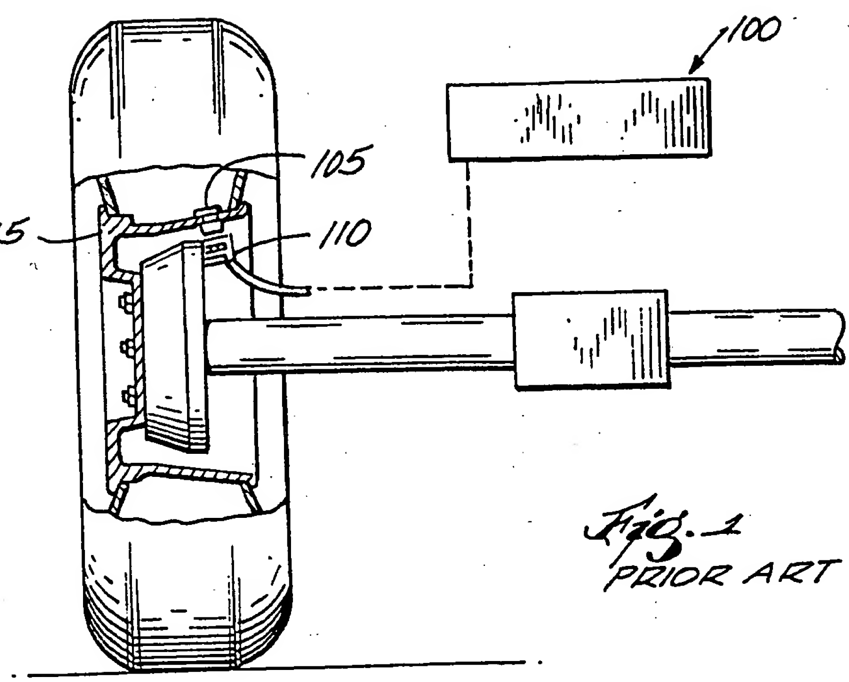

Fig. 1
PRIOR ART

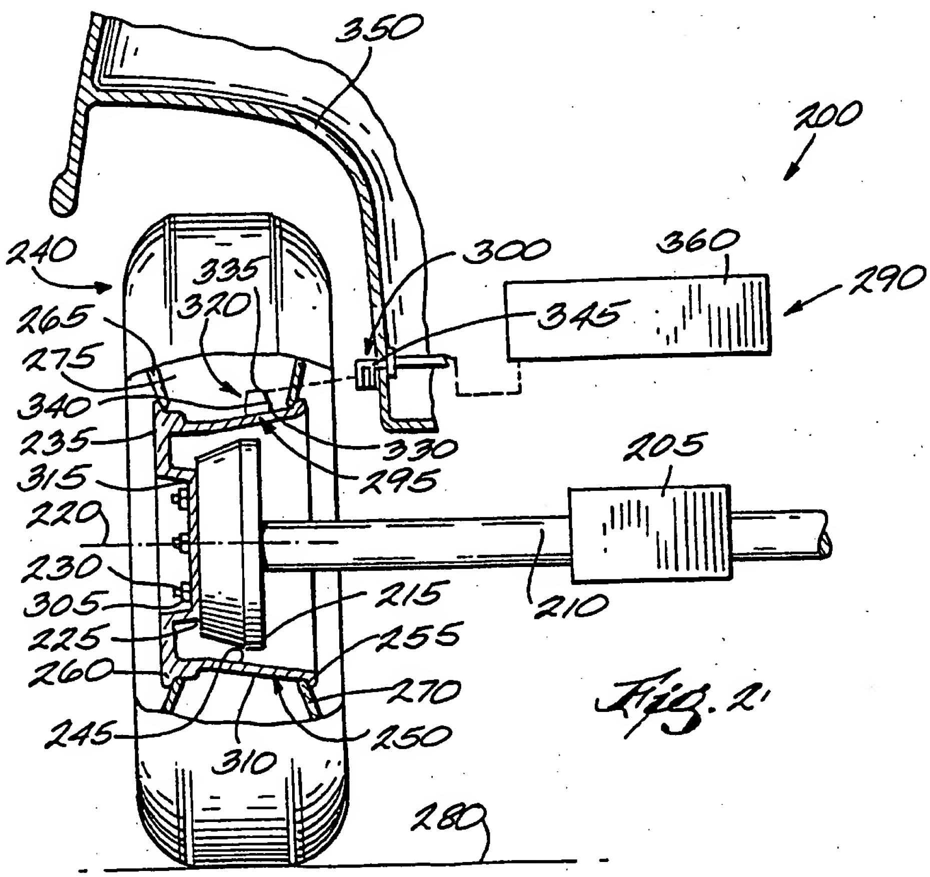

Fig. 2

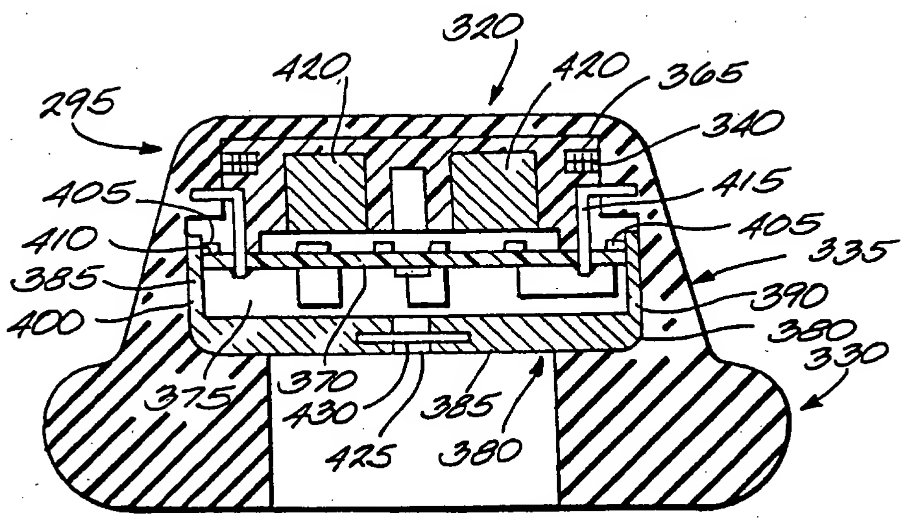
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Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/08020

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B60C 23/00, 23/02; G08B 1/08, 21/00; G01N 9/24
US CL :340/447, 442, 444, 539, 614, 626; 73/146.2
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 340/447, 442, 444, 539, 614, 626; 73/146.2

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,708,411 A [HILL] 13 January 1998, figs. 2 and 5	1-4,6,8-18
X	US 3,588,814 A (FURLONG) 28 June 1971, abstract	5,7
A	US 5,694,111 A (HUANG) 02 December 1997	1-18
A,P	US 5,749,984 A (FREY ET AL) 12 May 1998	1-18

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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